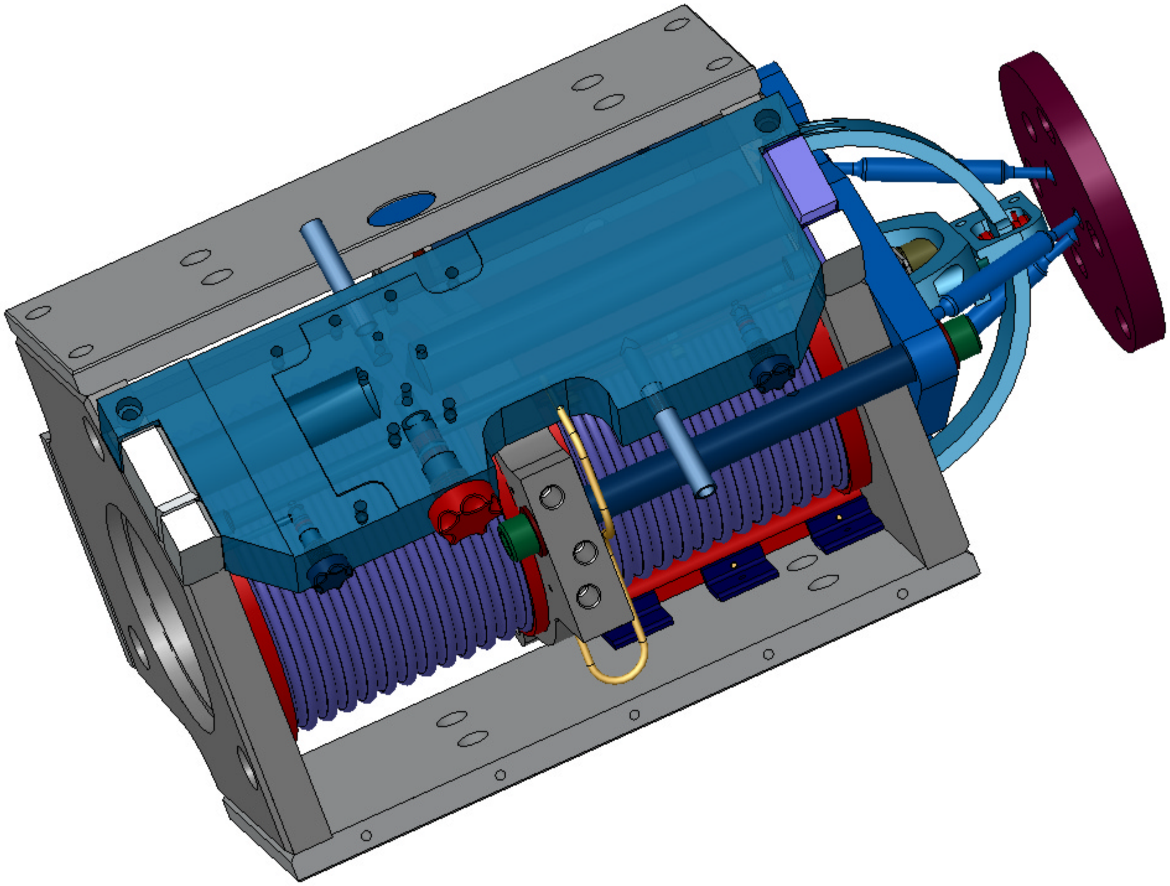
Hydraulic External Pre-Isolator

Brian Lantz, Corwin Hardham,
Dan DeBra, and a cast of thousands



Outline

Benefits of hydraulics

Installation at LASTI

Pump Station

Sensor Blending

Control loop shaping

Performance

Benefits of Hydraulics

Heating: Actuator dissipates 10W and heat is carried away by the working fluid.

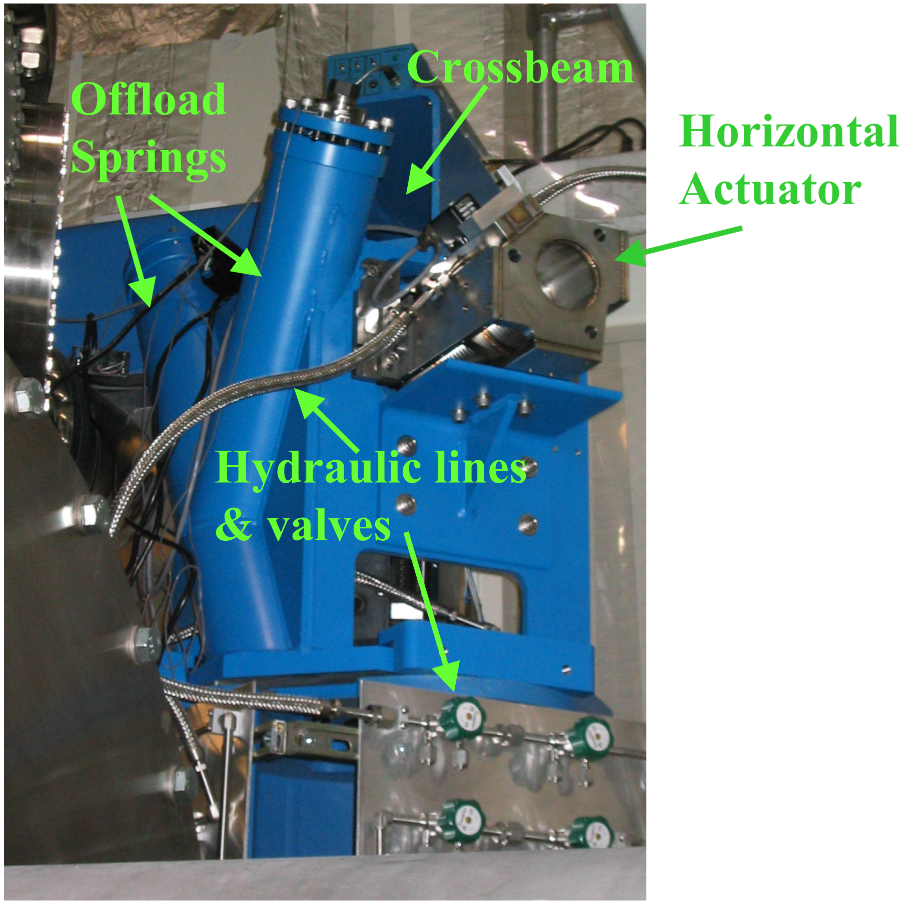
Range: +/- 1 mm gives headroom for seasonal drift, small earthquakes, tilts of the floor.

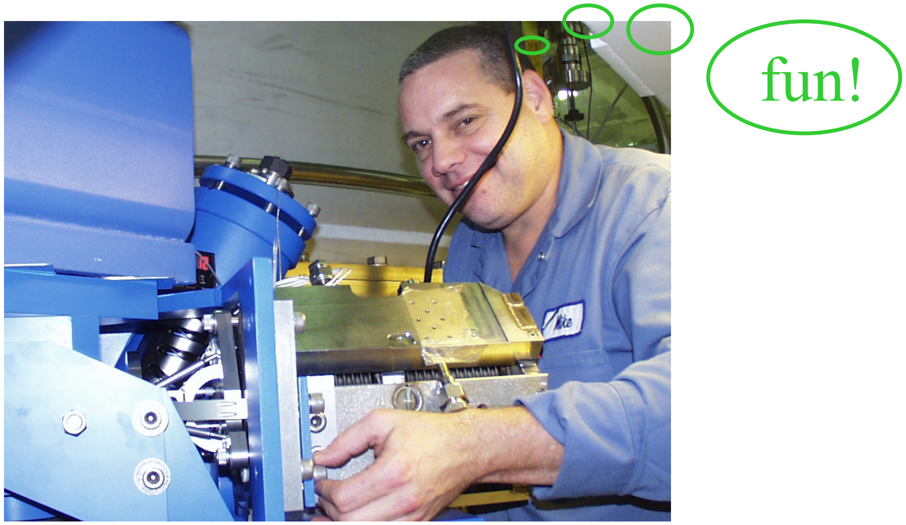
Response to saturation: Good recovery from saturation, simple loops and max velocity of 80 microns/ sec make recovery smooth.

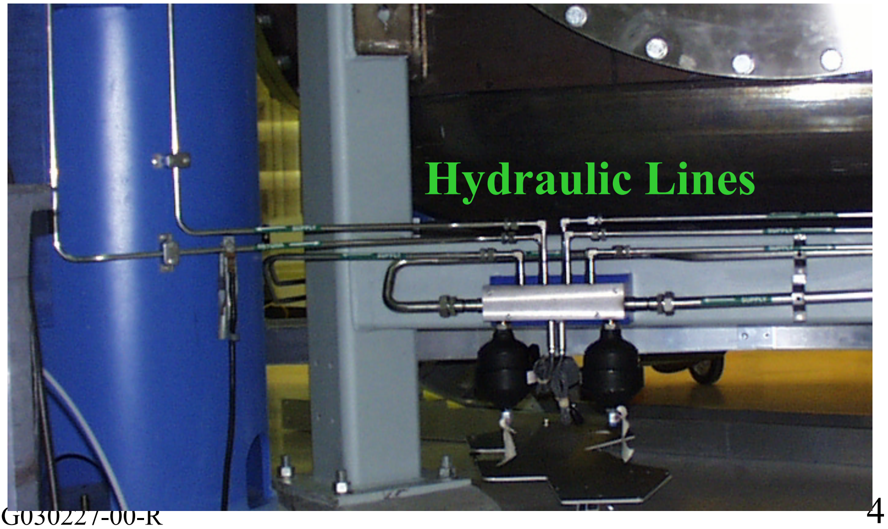
Damping of the elastic behavior of the stack – it’s like having a dashpot at the tip of the crossbeam.

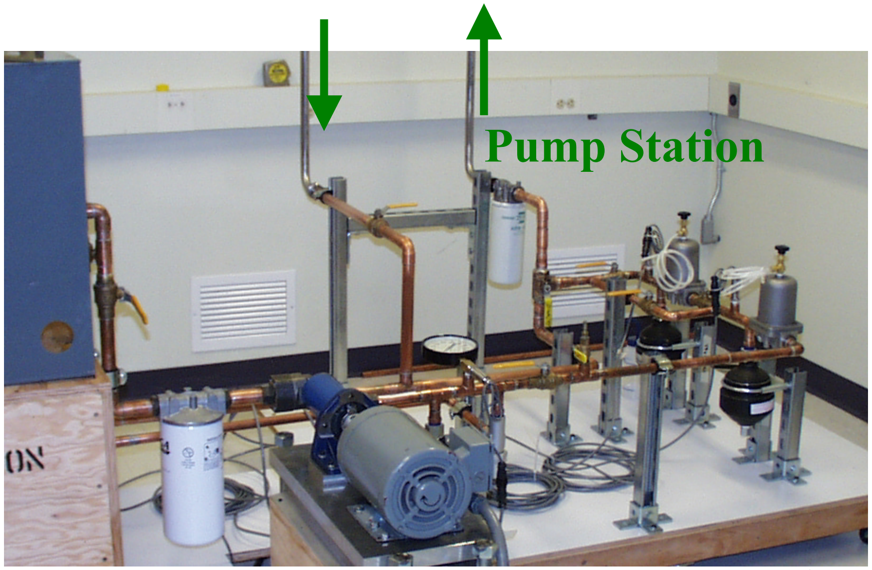
Stiffness gives large rejection of stack dynamics, makes control easy.

Hydraulic Installation

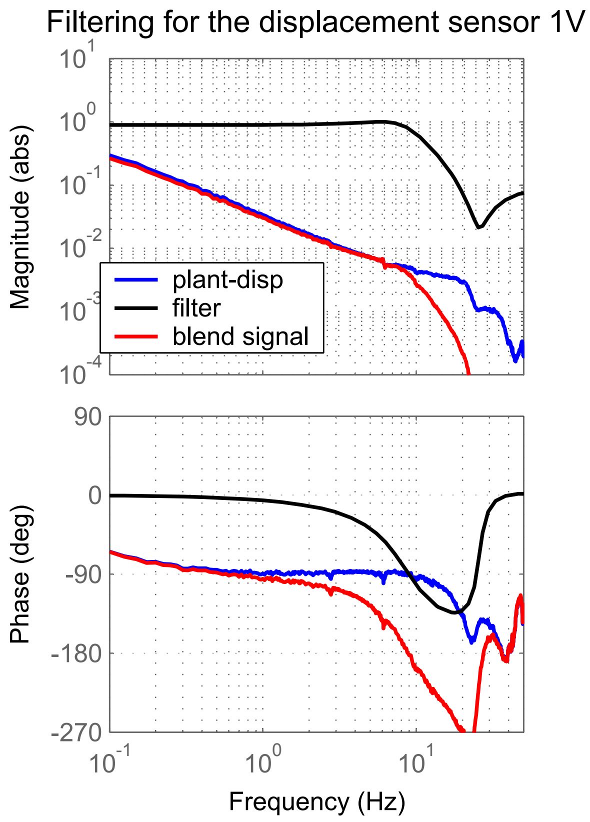




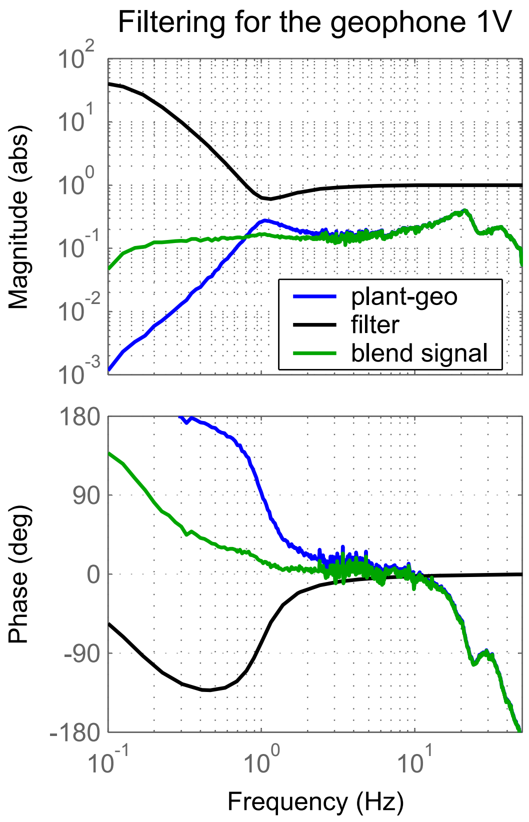




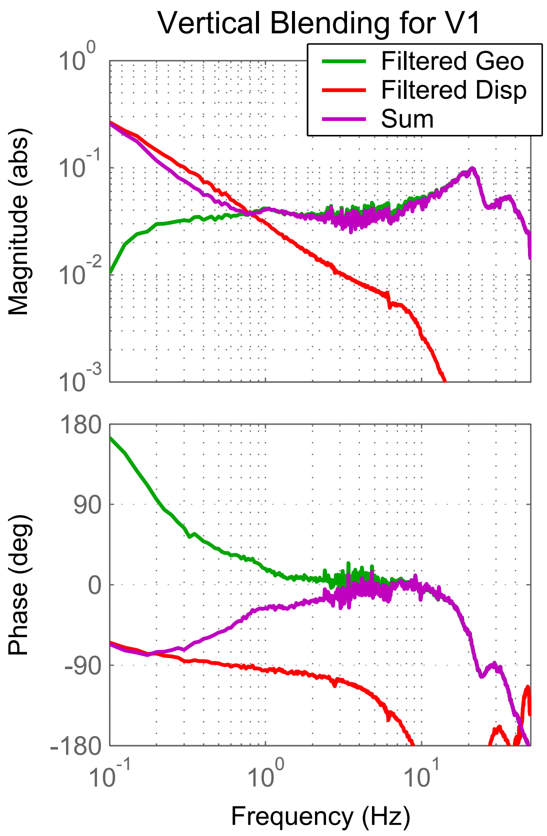
Sensor Blending, pier 1 Vertical



dewhitened displacement sensor response in mm/dspace drive. Filter attenuates above 10 Hz

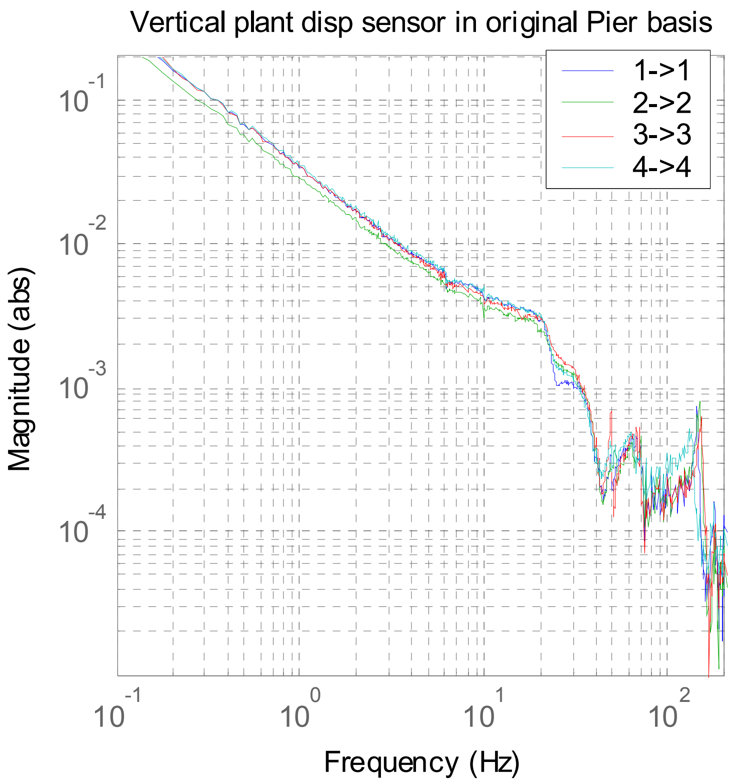


L-4C geophone has 1 Hz character response in dspace in/dspace drive. Filter “extends” low freq of geo

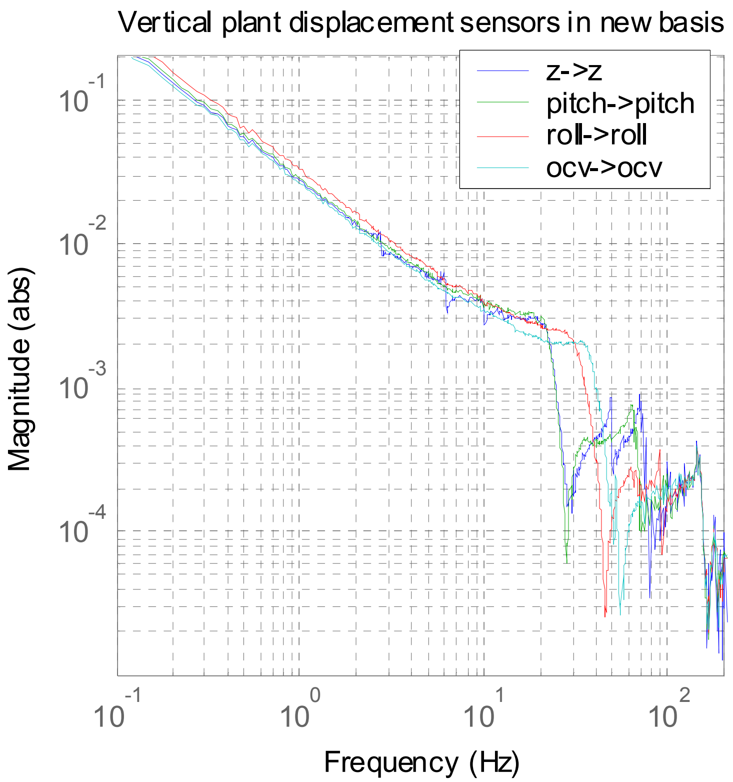


gain*filtered geophone crosses filtered displacement at 0.8 Hz to form supersensor.

Vertical Plant, diagonal terms

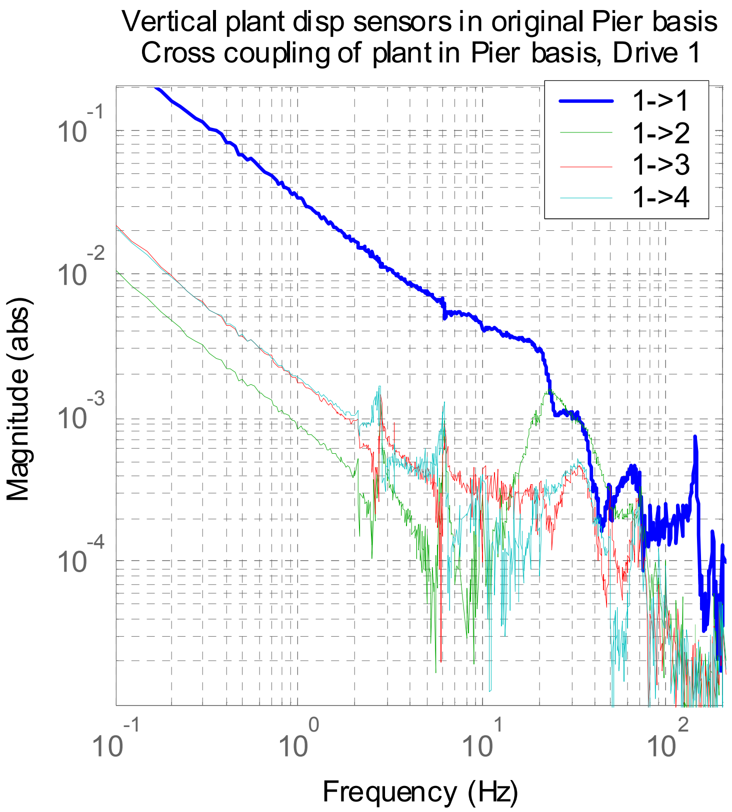

Vertical plant disp sensor in original Pier basis

Open loop response of the vertical disp. sensors to local drives (mm/dspace drive)
Corners all very similar, and couple to modes at 20 Hz and 30 Hz


Vertical plant displacement sensors in new basis

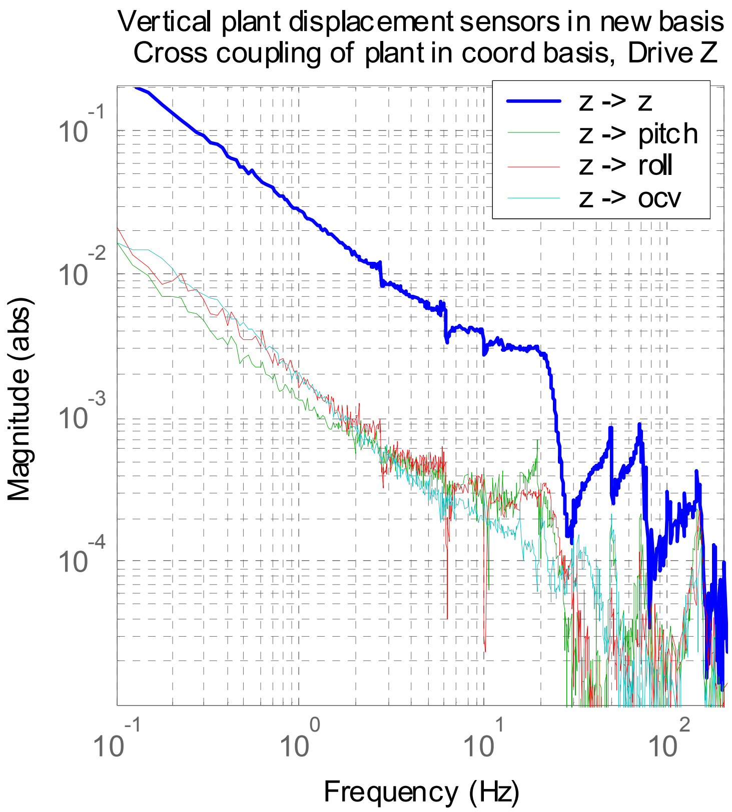
Open loop response of the vertical disp. sensors in the new “coordinate basis” (mm/dspace drive)
Directions still similar at low freq,
only couple to single mode at 20 Hz - 30 Hz

Vertical Plant, cross coupling



Open loop response of the 4 vertical disp. sensors to drives at pier 1 (mm/dspace drive)

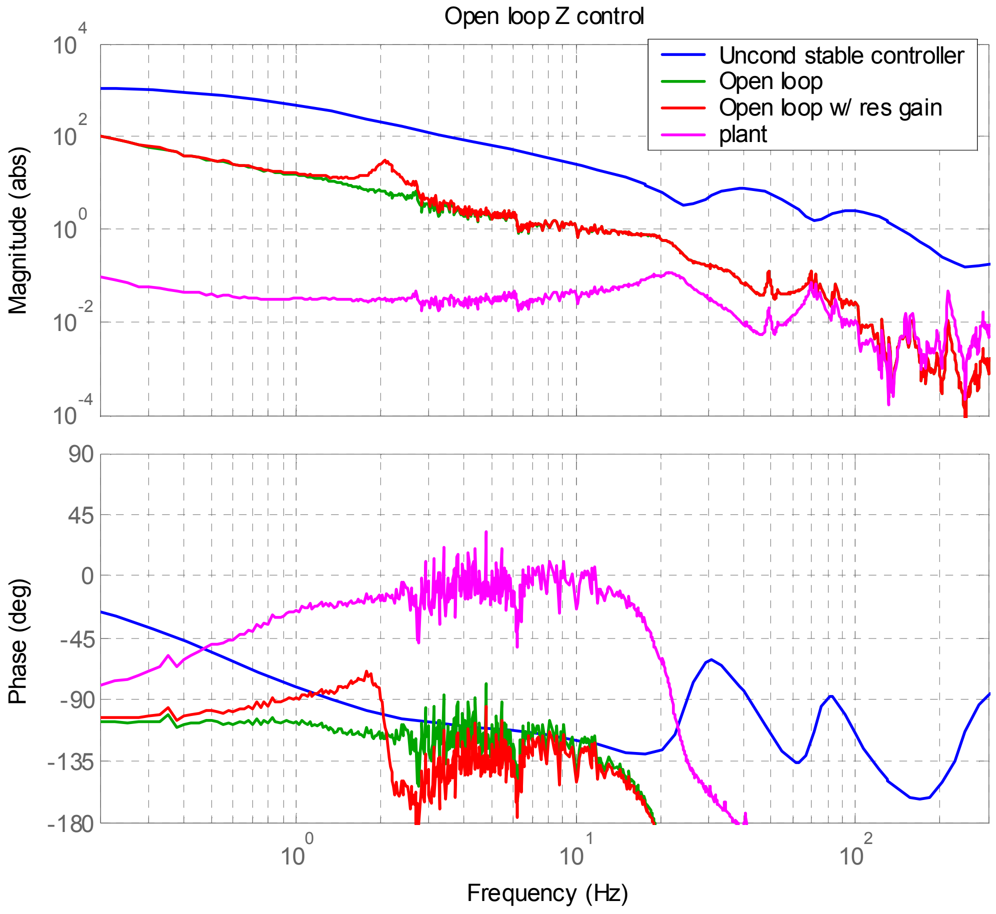
Corners 1 and 2 are coupled at 20 Hz (near the upper unity gain freq, they share a crossbeam)



Open loop response of the vertical disp. sensors in "coordinate basis" to z drive (mm/dspace drive)

Coupling is small

Blended Z control



Open Loop Transfer Function of

Blended Z plant – magnenta
(mm/dspace drive)

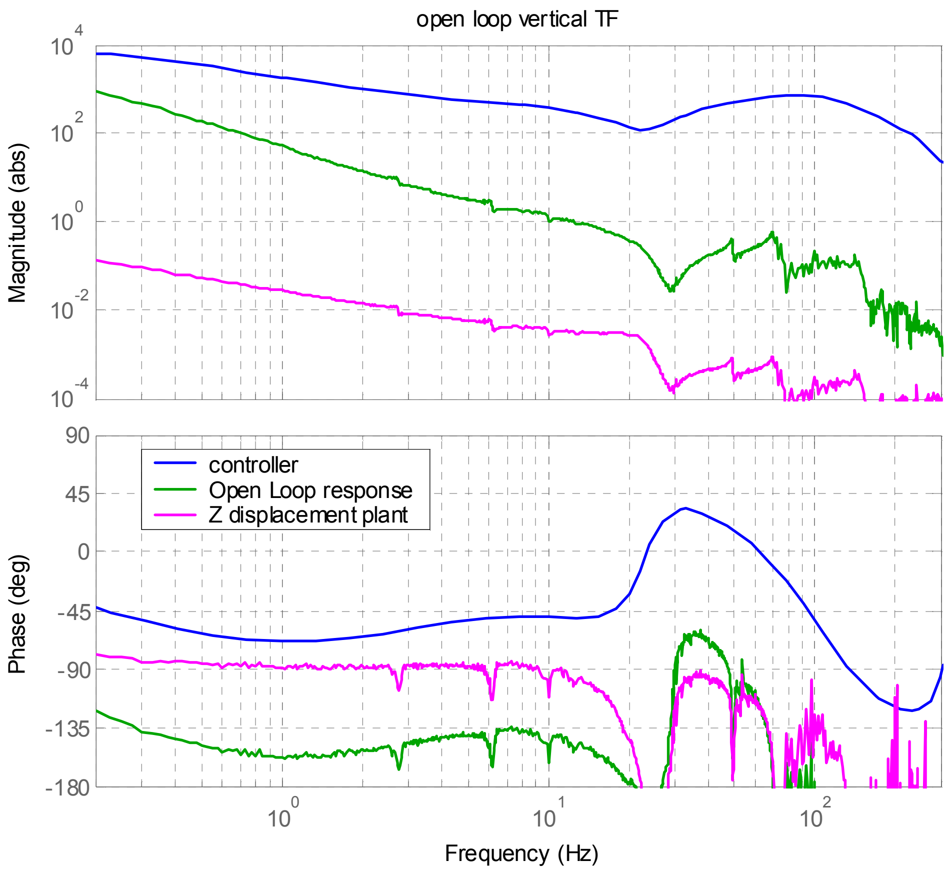
Controller – blue
(dspace drive/mm)

Open loop response (green)

Open loop with res. gain (red)

Controller is simple

Displacement Z control



Open Loop Transfer Function of

Disp. only Z plant – magnenta
(mm/dspace drive)

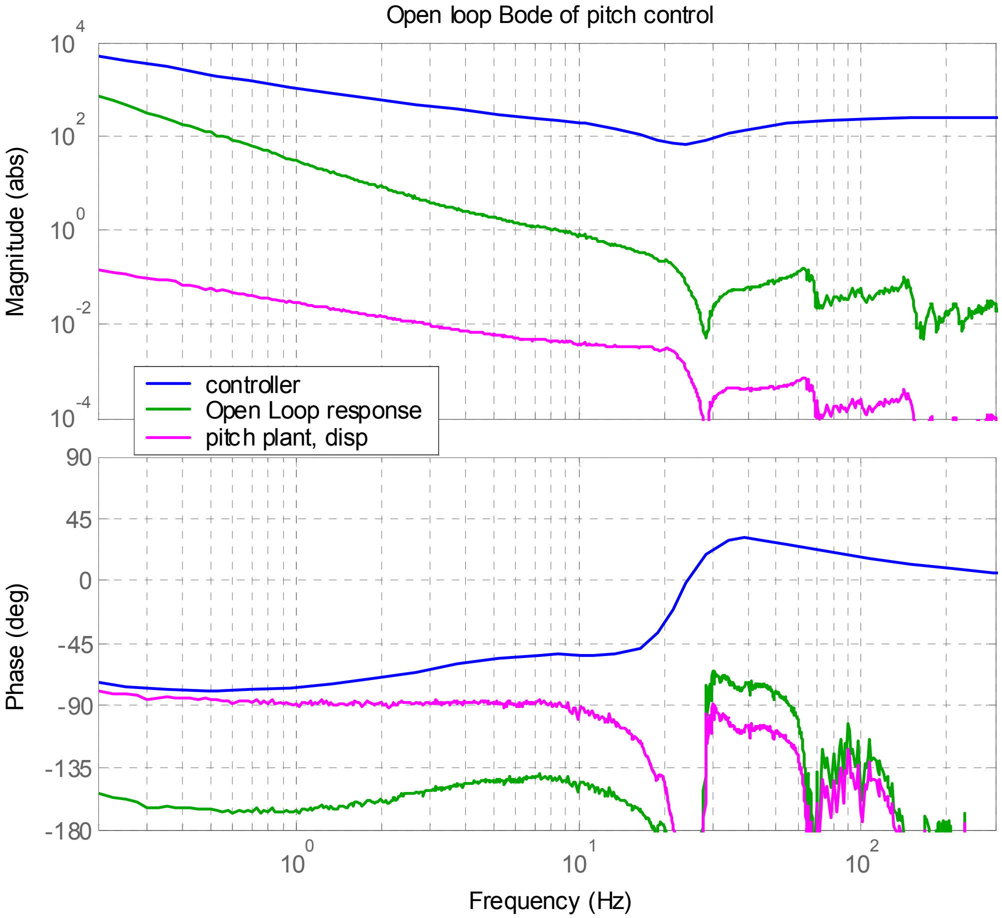
Controller – blue
(dspace drive/mm)

Open loop response (green)

Controller is really simple

Stack mode coupling at
2.9 and 6 Hz is small

Displacement Pitch control



Open Loop Transfer Function of

Disp. only pitch plant – magnenta
(mm/dspace drive)

Controller – blue
(dspace drive/mm)

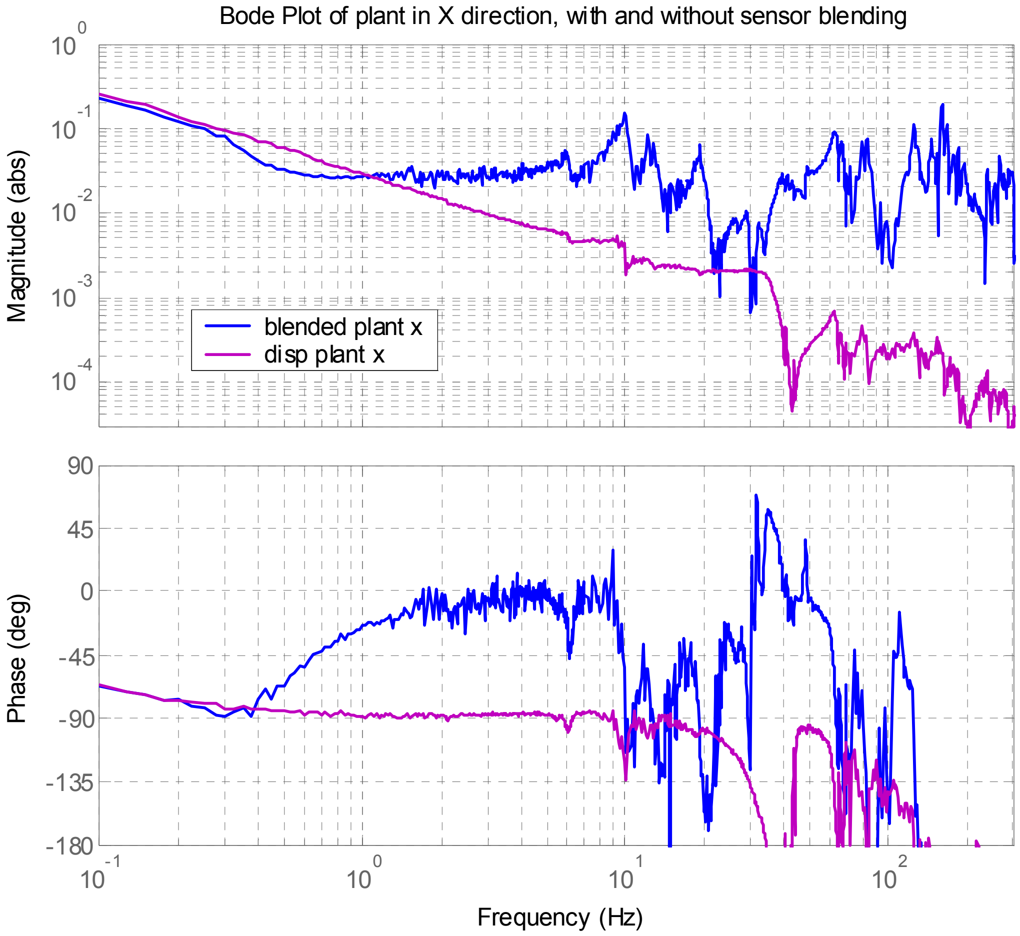
Open loop response (green)

Prototypical of all the rotation DOFs

Controller is really simple

Stack mode coupling not visible

Blending in X



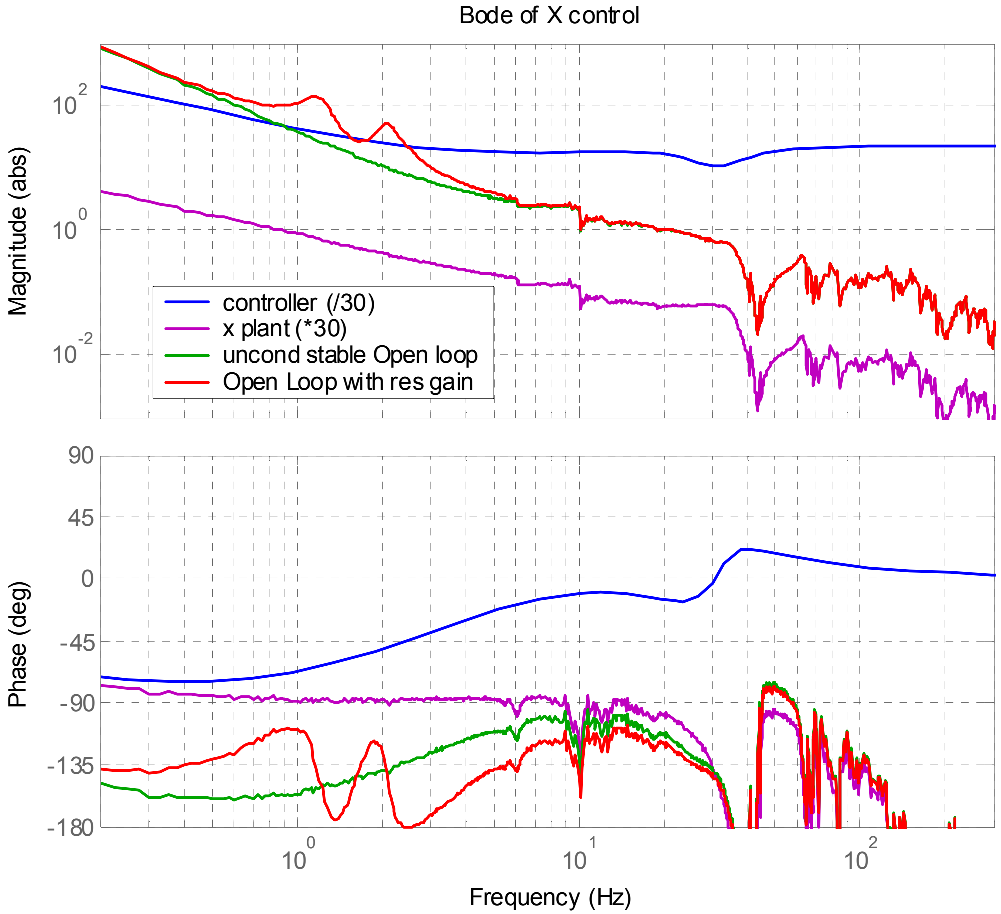
Open Loop Transfer Function of

Disp. only X plant – magenta
(mm/dspace drive)

Blended X plant – blue
(mm/dspace drive)

We use the displacement sensor only, as the dynamics are simpler

Control in X



Open Loop Transfer Function of

Disp. only X plant – magnenta
(mm/dspace drive)

Controller – blue
(dspace drive/mm)

Open loop system (green)

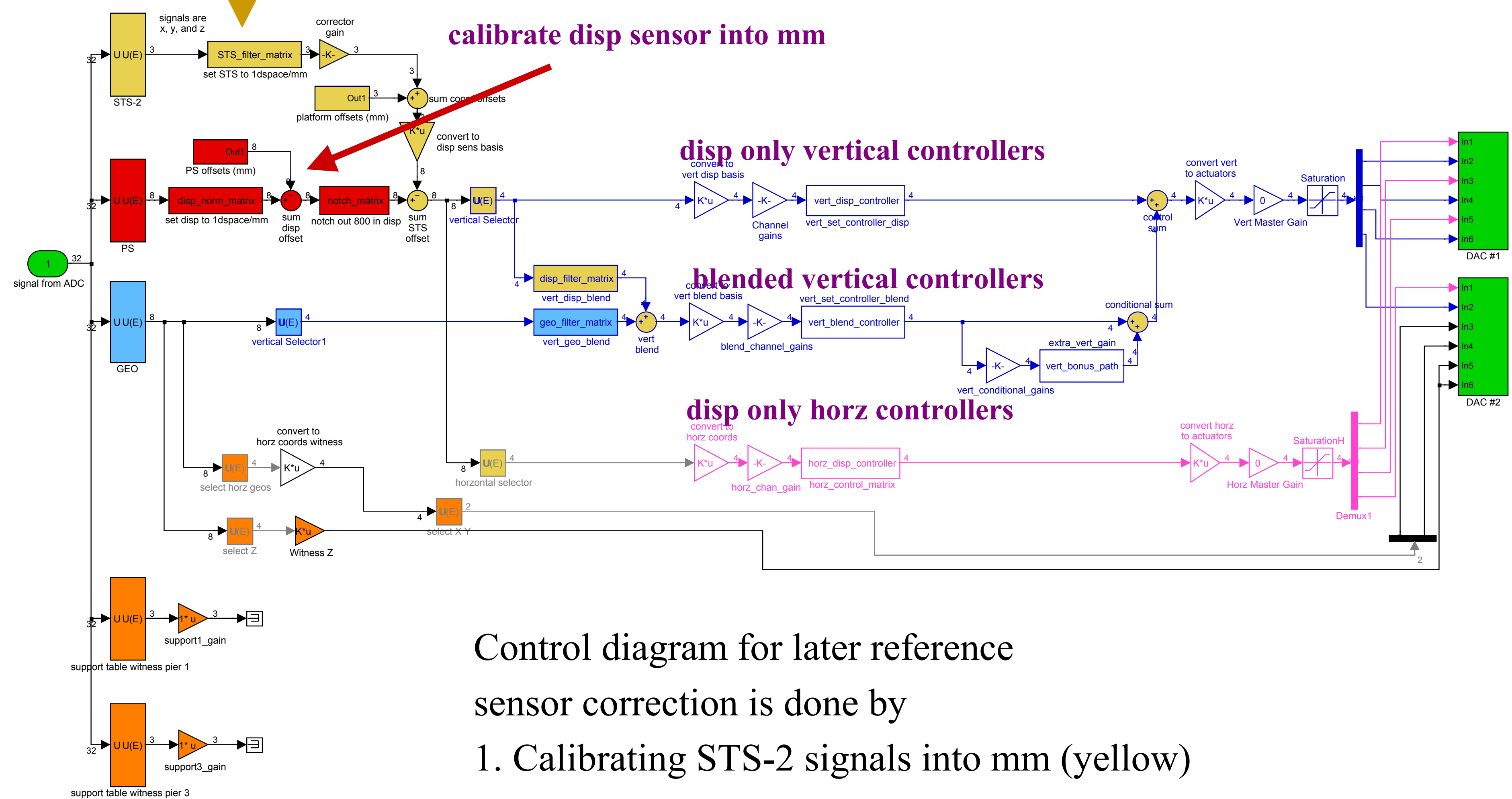
Open loop with res. gain (red)

Prototypical of X and Y DOFs

Controller is simple

Stack mode coupling is small

Control Diagram


calibrate ground motion into mm

calibrate disp sensor into mm

disp only vertical controllers

blended vertical controllers

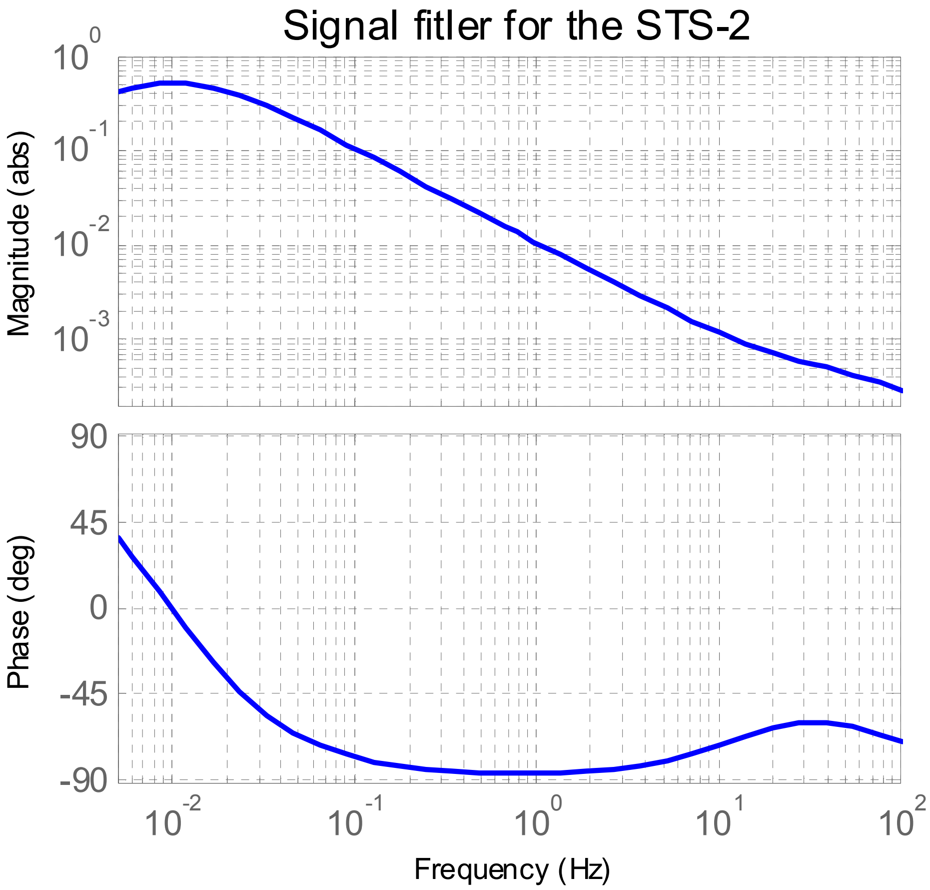
disp only horz controllers

Control diagram for later reference

sensor correction is done by

1. Calibrating STS-2 signals into mm (yellow)
2. Calibrating disp signals into mm (red)
3. Subtracting

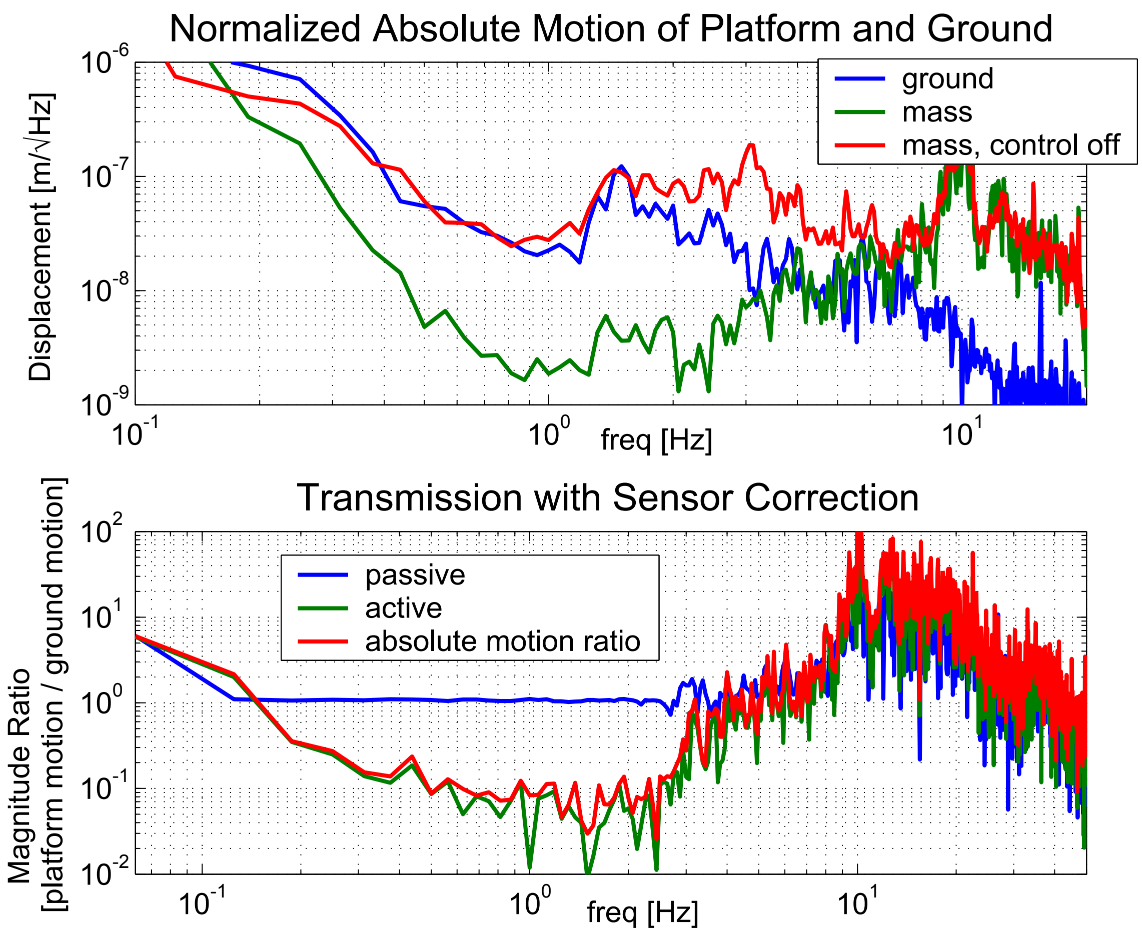
Sensor Correction



Transfer Function of the Corrector

- Integrate and calibrate the STS-2 signal
- Output signal is mm of ground motion
- Directly subtract from the calibrated displacement sensor
- Same for various systems

Performance in X



Performance measures:

Top plot shows ASDs of motion:

Ground (blue)

Support table with control off (red)

Support table with control on (green)

Lower plot shows ratios:

Transmission with control off (blue)

Transmission with control on (green)

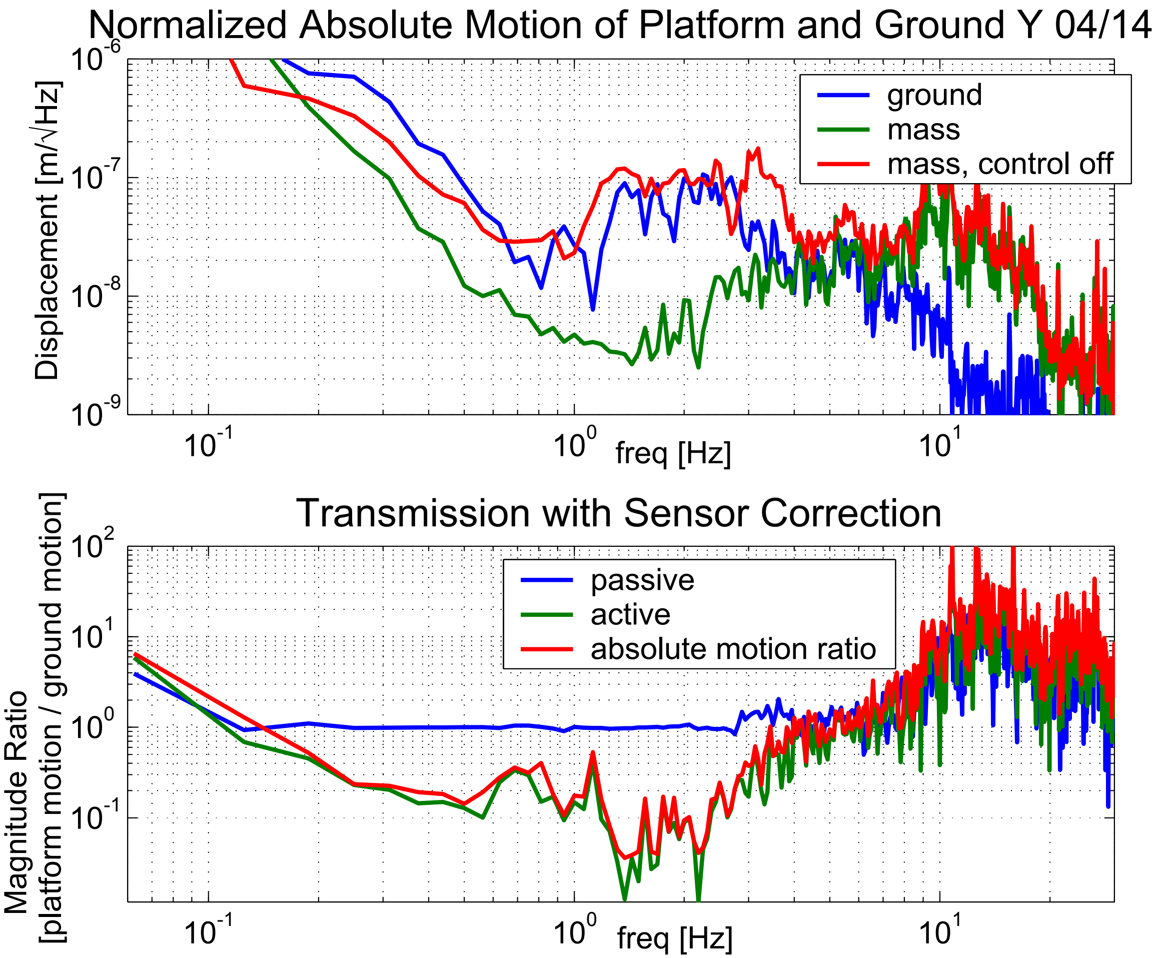
Relative motion with control on (red)

Good performance.

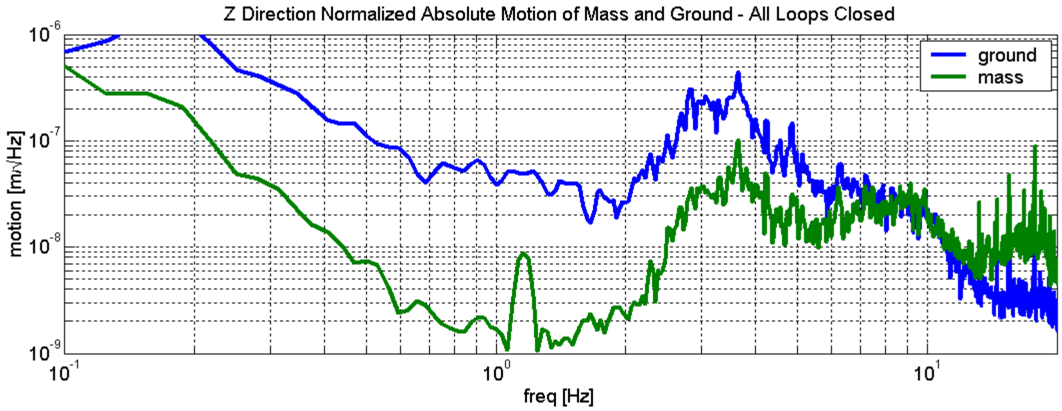
See motion of 2e-9 m/rtHz

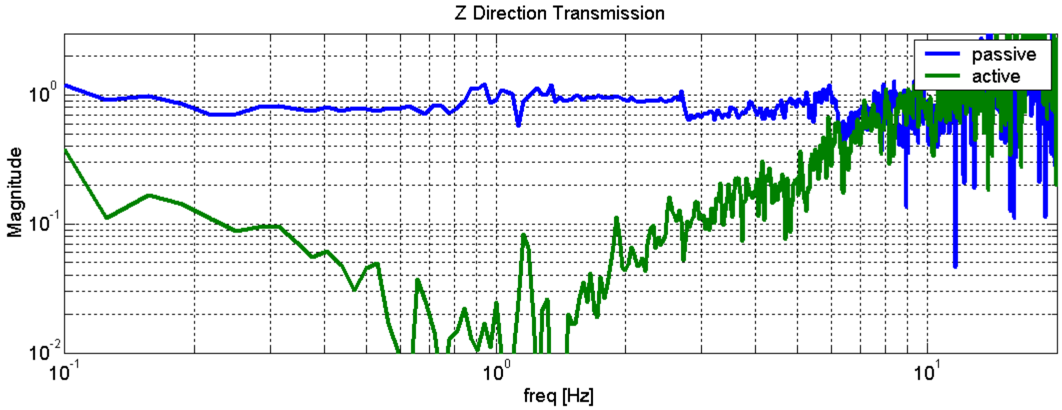
Match of trans&ratio indicates limits are loop gain and correction match.

Performance in Y



Performance in Z





January data for z direction,
a good set of data.
Top plot shows ASDs of motion:
Ground (blue)
Support table with control on (green)

Lower plot shows ratios:
Transmission with control off (blue)
Transmission with control on (green)

Peak above 1 Hz is ADC noise
Performance not always this good –
Coupling between payload motion
and the ground motion STS-2?

In Conclusion,

We believe the hydraulic actuator is the right choice for this application.

Need to investigate the slab bending.

The control is simple, and the isolation performance can be quite good.

System is quite robust to big control inputs, people walking around, trucks outside (performance is not so good, but it doesn’t break, and is rate limited to 80 microns/sec)

Extra slide – pump noise